

PROPOSAL CRP AND FLAGSHIP NARRATIVES

Livestock Agri-food Systems

CGIAR Research Program

Presented by the International Livestock Research Institute (ILRI) with :
German Development Agency (GIZ), International Center for Agricultural
Research in Dry Areas (ICARDA), International Center for Tropical Agriculture
(CIAT), International Water Management Institute (IWMI), Swedish University
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Agroforestry Center (ICRAF)



Science for a food secure future



Proposal

Livestock Agri-Food Systems CGIAR Research Program FEED AND FORAGES FLAGSHIP NARRATIVE

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2.3. Livestock Feeds and Forages

2.3.1 Livestock Feeds and Forages Flagship Narrative

Improving the productivity of livestock in low and middle-income countries (LMIC) has the potential to transform human nutrition and farmer livelihoods. Along with better animal health and improved genetics, better feeding can bring about transformative change, but success thus far has proved to be variable and limited. We have identified a number of key constraints to improved feeding that the CGIAR and its partners are well placed to tackle through research.

This flagship will:

- Update evolving global knowledge on appropriate feed solutions and make this knowledge widely available through simple tools.
- Develop a suite of approaches for getting feeds where they are needed, when they are needed.
- Apply research to the development of small-scale business models and employment creation and a stronger delivery environment for feed solutions.
- Apply better targeted breeding approaches for forages and full-purpose crops to produce feeds and forages that are suitable for a rapidly changing livestock sector.

The first three of these research lines aims to make better use of existing technologies in the short to medium term while the fourth seeks to provide new solutions for the future. These research lines learn from previous research, play to the strengths of the CGIAR centres and fit the needs of a rapidly changing livestock sector. The CGIAR feeds team brings a wealth of world-leading research strength and knowledge to bear on the challenge of improved feeding of LMIC livestock and the proposed programme has potential for significant impact on the livestock feed sector.

Research will contribute directly to three sub-IDs, by targeting the following outcomes:

- Closed (livestock) yield gaps through improved agronomic and animal husbandry practices.
- More efficient use of inputs, specifically stress-tolerant feed and forage options.
- Technologies that reduce women's labour and energy expenditure developed and disseminated, addressed through efficiency gains in forage and feed production, sourcing and processing.

2.3.1.1. Rationale and scope

Why research on animal feeds and forages in developing countries?

Animal-source foods (ASF) such as milk, meat and eggs offer strong nutritional benefits in Low and Middle Income Countries (LMICs). Demand for ASF is increasing and this offers multiple opportunities for livestock producers to be part of the supply response and so improve their livelihoods. But this requires a step change in productivity in which better animal nutrition and feeding of livestock is critical.

Feed is a key limiting factor and often the most expensive input in livestock production (Swanepoel *et al.*, 2010), representing up to 50 - 70 % of production costs, depending on the system. Integrating feed and forage research with improved animal health and genetics has the potential to dramatically increase livestock production - by 2- or 3-fold according to Herrero *et al.* (2016). In mixed crop-livestock systems, which often have high potential to intensify, the most important contributors to feed resources are forages, crop residues and pastures (Herrero *et al.*, 2013), while in pastoral and agro-pastoral systems, grazing of rangelands is the principal, and often the only, source of feed.

Feed shortages, in terms of both quantity and nutritional quality, occur either seasonally or, in the case of dryland pastoral systems, inter-annually. They are widespread, slow the sector's growth and periodically cause losses of productivity and even loss of animals. Improved feed and forage options, better management of rangeland, increased cut-and-carry and grassland resources, together with improved feed utilization of crop residues and other agricultural by-products, all have underexploited potential to improve animal productivity, while also contributing to the resilience of agro-ecosystems, environmental sustainability (Smith *et al.*, 2013b; Searchinger *et al.*, 2015; Rao *et al.*, 2015) and equity. Despite the transformative potential of improved feeding, progress in LMICs has thus far been variable

and limited and **major researchable constraints and opportunities** remain which need to be identified and quantified. **Feeding options need to be developed** that take account of the varied livestock systems and circumstances of farming communities and made available to farmers – no one size fits all and this has often not been appreciated in the past. Furthermore, livestock systems are subject to rapid change related to climate change, intensification and urbanization; new feed options, including better adapted forages and food feed crops that address the new challenges, are needed. A further constraint is the low nutritional value of crop residues that form the basal diet for much of the LMIC livestock population and require upgrading, so **better use can be made of existing feed resources**.

Research is needed to strengthen the institutional environment for **delivery and scaling of new feed and forage options** and for understanding and exploiting benefits for women and youth. As farmers seek to boost productivity and rely increasingly on off-farm feed and forage sources, small-scale entrepreneurs and other market actors require better business skills to enable their transformative role in the smallholder sector.

There is thus a mix of technical and institutional barriers to improved livestock feeding in LMICs which requires a concerted and integrated research effort to which the CGIAR centres are well-placed to tackle through research.

Addressing the grand challenges

This flagship will contribute to several of the grand challenges. Feed and forage research to improve animal nutrition for increased productivity will help to combat malnutrition and ensure nutritious and diverse agri-food systems and diets. Feed based options provide job opportunities, e.g. for women and young people, mitigating gender inequity and labour constraints. Environmental factors, such as competition for land, overdrawn water supplies, soil degradation and climate change, are all affected, positively or negatively by the production and management of feeds and forages.

Why should CGIAR invest in this?

There has been much research in this area by CGIAR centres, NARS and private sector over many years. Cross-CGIAR centre work to synthesize global knowledge on the range of existing feed options and make it readily available to development actors through tools such as SoFT (www.tropicalforages.info) and FEAST (www.ilri.org/feast) has been widely taken up. These tools, coupled with capacity to undertake foresight research make the CGIAR centres well placed to carry out research on feed and forage options based on both agro-ecological suitability, specific demands for different livestock systems but also on suitability to socio-economic conditions such as land and labour availability and market conditions, including gender-differentiated opportunities.

The CGIAR is pre-eminent in the area of forage breeding, as highlighted by collaboration with two multinational companies¹ relying on CIAT's tropical forage breeding. This has led to the release of the first commercial *Urochloa* (syn. *Brachiaria*) hybrid in 2003 and the continued release of further hybrids for targeted production niches. It is estimated that there are currently over 700,000 ha of *Urochloa*² hybrids sown originating from the breeding programs³. The pioneering CGIAR cross-centre and cross-CRP research on the nutritional quality of crop residues and potential for upgrading through breeding and selection and amendments of new cultivar release criteria is gaining traction in cereal breeding efforts, including interest from seed companies. This will be further developed as Cross-CGIAR Full-Purpose Crop Initiative, led by this Flagship.

Access to global gene bank resources, including the Genebank Platform (e.g. the 'Use Module') and the Excellence in Breeding platform, provides opportunities for forage selection and breeding that are unique to the CGIAR. Work on breed improvement for open pollinated varieties (OPVs), such as dual purpose and forage legumes where there are limited financial incentives for private sector breeding efforts, is another obvious niche.

¹ Dow Agrosciences and Grupo Papalotla

² Independent of farm-size, *Urochloa*, *Megathyrsus* and *Pennisetum* are the most widely used tropical forages

³ http://livestock-fish.wikispaces.com/file/detail/Seed+Sales+Brachiaria+Hybrids_CIAT.xlsx

There is also a role for the CGIAR related to its focus on small- and medium-sized farms which may be of less interest to the private sector but which could reach tipping points as they intensify and demand for ASF is increasing. CGIAR research can play a catalytic role in facilitating the public and private sectors to work together as demonstrated in a recent project in Ethiopia (Negassa et al., 2016). Finally, the CGIAR centres are well placed to leverage frontier research by global players based in industrialized economies for the benefit of LMIC beneficiaries; e.g. discovery and adaptive research on improving the nutritional quality of ligno-cellulosic material based on spin-offs from 2nd generation biofuel research where the digestibility of cereal crop residues can be increased to 70% and beyond.

In summary, the proposed research learns from the past but represents a new approach to the feed problem that plays to the strengths of the CGIAR centres. It does this based on realization that adoptable feed options are context specific and need to be tailored locally rather than attempting to rely on blanket feed solutions. We are capitalizing on our strengths in breeding and using this to develop forages that keep pace with a dynamic livestock sector using our track record in Latin America to accelerate progress in Sub-Saharan Africa and South-East Asia. We are profiting from our relationships with the crop centres to move the emphasis of breeding programmes towards the “full-purpose crop” concept, with specific application in situations with high population densities constrained by land availability such as South Asia and parts of Africa. We are applying our systems perspective to the issues of how to get feed to where it is needed, when it is needed and how to foster gender sensitive micro-business in support of improved feed supply. We have moved strongly in the direction of connecting our feed improvement work to markets for livestock products. We are giving increasing focus to SME business opportunities along the feed value chain and applying research approaches to the question of how to deliver solutions in a weak institutional context. Research will inform and support the emerging/nascent private and public sectors. We believe that these research approaches will make a significant contribution to improving livestock feed supply and quality in the next 3-6 years and avoiding feed holding back gains from improved livestock genetics and health.

Amidst the various strengths and weaknesses in the livestock feed research arena, the CGIAR brings unique added value. Its particular strength is in its global reach and the opportunity this offers: the broad view of livestock systems derived from experience of research in diverse contexts allows a quality of livestock feeding systems research that goes beyond that done by the NARS with their national mandates.

Overall goal: Increased animal productivity through better animal nutrition by providing superior, business-oriented feed and forage strategies and options.

2.3.1.2 Objectives and targets

Contribution to SLOs: Research in this flagship will contribute directly to two SLOs - reduced poverty and improved food and nutrition security for health - and indirectly to a further SLO - improved natural resource systems and ecosystem services.

The flagship aims to reach 1.18 million households by 2022 with improved feeding options and strategies that will increase livestock productivity by over 30% per unit area of production. Many of these beneficiaries will be women and young people, who will enjoy higher incomes and increased job opportunities, as well as improved nutrition. Most will be small- and medium-scale livestock producers, but non-livestock keepers engaged in feed and forage value chains will also benefit, in both ‘rapid inclusive growth’ and ‘fragile growth’ systems⁴. The flagship will also conduct research to help realize the opportunities for youth employment within feeds/forages and livestock value chains.

Research will contribute directly to three sub-IDs, by targeting the following outcomes:

- Closed (livestock) yield gaps through improved agronomic and animal husbandry practices.
- More efficient use of inputs, specifically stress-tolerant feed and forage options.
- Technologies that reduce women’s labour and energy expenditure developed and disseminated, addressed through efficiency gains in forage and feed production, sourcing and

⁴ For explanation of growth trajectories see CRP Livestock Full Proposal p.28

processing.

This flagship's objectives are:

- **Synthesize global knowledge on livestock feed options** and package it into widely available tools for feed solution targeting (Cluster 1).
- **Develop improved feed and forage genetic options** that are better suited to abiotic/biotic pressures such as drought and disease/pests and that improve the efficiency of livestock-tree-crop systems as a whole, achieving higher productivity at lower resource use (land, water, fertilizer, labour among others) (Cluster 2).
- **Target, test and disseminate feed, fodder and forage utilization and processing options to make better use of existing feed resources** in small-scale production systems undergoing rapid inclusive or fragile growth (Cluster 3).
- **Take promising new and existing feed and forage technologies to scale**, by developing, testing and implementing innovative business models and scaling approaches together with the value chain stakeholders (Cluster 4).

Flagship outcomes to 2022

- 1.13 million poor households (5.1 million individuals) efficiently using inputs through optimized feeding strategies, including rations and processing across 11 countries.
- 1.18 million poor households (5.4 million individuals) realizing 30% increase, on average, in livestock productivity through the use of improved feeding options and strategies, in 12 countries.
- Improved feeding practices that reduce women's labour and energy expenditure by 10% developed and disseminated, reaching 1.6 million women in 12 countries.

2.3.1.3 Impact pathway and theory of change

Figures 2.3a and 2.3b present the flagship's theory of change (ToC) and assumptions. In simple terms, the programme's ToC involves, by responding to current and projected demands, the development of research outputs (Sphere of Control) which are taken up, promoted and facilitated by next users (Sphere of Influence) and lead to our targeted outcomes and impacts (Sphere of Interest). Thus, for example, for Cluster 1 we will develop e.g.:

- Refined tools to analyse local, national and regional feed supply and demand, e.g. food-feed supply scenarios, NIRS. Application: global.

If our ToC is correct, these outputs will be taken up, promoted and facilitated by research and development partners and decision makers who will apply these approaches for better targeting of feed solutions. This will mean that local, national and international research and development partners are better able to diagnose feed constraints and opportunities and to effectively prioritize and target feed and forage interventions. Following through our ToC logic, this better prioritization and targeting of interventions will have impacts on our Sub-IDs: "Closed (livestock) yield gaps through improved agronomic and animal husbandry practices" and "More efficient use of inputs".

A similar logic applies to each of our Clusters of Activities and can be followed graphically in Figure 2.3a. Our assumptions are listed in Fig 2.3b. For example, we assume that our hypothesis is correct that better matching of feed options to local constraints is the limiting constraint to enhanced feeding (Assumption A2). Fig 2.3b also points to the Domains of Change within our Sphere of Influence to show key areas where we anticipate behavioural change to support contribution to our Development Outcomes. Finally, in Fig 2.3b we show where Enabling Cross-cutting Actions, such as capacity development, gender and youth and markets, will be needed to foster the Outcomes we are targeting.

2.3.1.4 Science quality

The flagship team represents a broad range of scientific expertise. It brings together a multi-disciplinary team of internationally recognized scientists, with expertise in participatory methods, practical application of nutritional science at field level, molecular biology, plant breeding, pathology, physiology, systems agronomy, rangeland ecology, innovation systems approaches and business

development.

Recent research by team members demonstrates the progress we have been achieving in our priority areas as well as the science quality that the team brings to the feeds and forages research area. In the area of tools and prioritization (Cluster 1), spatial rangeland monitoring technologies have allowed the study of the effects of water salinity and drought on key species (Louhaichi *et al.*, 2010, 2015; Ouled Belgacem and Louhaichi, 2013). The team developed the FEAST methodology for prioritization of feed interventions and the approach has been widely adopted internationally by both the research and development communities. The team also developed a selection tool for tropical forages (SoFT), which is accessed by approximately 300,000 users/year.

For genetic improvement (Cluster 2), forage breeding expertise has been used to develop methodologies for the selection of stress-tolerant and highly nutritive forage and rangeland germplasm (Rao *et al.*, 2014). Advances in *Urochloa* phenotyping have allowed the identification of new genetic materials with high potential for breeding (Rao *et al.*, 2014; Cardoso *et al.*, 2013, 2014a, 2014b) as well as high biomass production, nutritive quality and resilience (Rao *et al.*, 2015). Development of new *Urochloa* hybrids with different levels of biological nitrification inhibition (BNI) activity paves the way for use of BNI as a genetic mitigation strategy to address food security and climate change (Arango *et al.*, 2014; Rao *et al.*, 2014; Subbarao *et al.*, 2017). For full-purpose crops, it has shown that breeding can simultaneously increase crop residue feed quality and water use efficiency (Blümmel *et al.*, 2015). Genome-wide association studies (GWAS) have been applied to inbred lines from CIMMYT's Drought tolerant maize for Africa (DTMA) program. GWAS has paved the way for genetic improvement of important traits in stover (Vinayan *et al.*, 2013). Feeding options that reduce methane emissions from livestock have also been identified (Hatew *et al.*, 2015).

For feed utilization (Cluster 3), the Livestock and Fish CRP saw advances in the development of demand scenarios and domains for selected crops (e.g. maize, sorghum, cowpea) and geographies (Blümmel *et al.*, 2013; Singh *et al.*, 2003) to inform decisions on new full-purpose crop cultivars.

For Cluster 4 (scaling) advances have been made in understanding how candidate feed solutions need to connect to the wider value chain system and the role of stakeholder networks in facilitating this (Ayele *et al.*, 2012). In the GIZ Feedseed project, approaches were piloted for small-scale forage seed businesses; leading to establishment of a seed producers association in Ethiopia (Negassa *et al.*, 2016).

The flagship will build on this track record by developing some exciting new areas of research. For Cluster 1 (tools and prioritization) the work acknowledges that feed solutions vary due to dynamic and changing environments. Simple approaches to connect solutions to individual contexts are needed. This process has already begun with the development of prioritization and selection tools such as FEAST and SoFT which combine tacit knowledge from the global feeds and forages science community with biophysical and other information to address the challenges of matching feeds and forages to different situations. This effort will be advanced in this flagship. Food-feed supply scenarios will help to refine research and development needs. Further strands of work will capitalize on cutting edge techniques that improve genetic gain, such as advances in phenotyping (e.g. NIRS and remote sensing to better match feed solutions to local contexts) and genotyping. Foresight approaches (González *et al.*, 2017) including ex-ante/-post impact assessment, crucial to continuously refine research efforts to respond to highly dynamic production contexts and demand, will be given particular attention.

Under Cluster 2 (genetic Improvement) we will use recent developments in genomics (e.g. Abera Desta and Ortiz, 2014) and in the management and analysis of big data (e.g. Berger *et al.*, 2013) to achieve increased efficiency in the development of new forages. We will link with the CGIAR Excellence in Breeding Platform (<http://excellenceinbreeding.org/>), the Genebank Platform and Platform for Big Data in Agriculture to develop improved forage cultivars with enhanced performance under biotic and abiotic stresses (Rao, 2014; Cardoso *et al.*, 2014a; Jimenez *et al.*, 2017; Hernandez *et al.*, 2017). Dense maps and reference genomes will be constructed for complex polyploid forage species (Farrell *et al.*, 2014; Li *et al.*, 2014), enabling genomic selection (Hayes *et al.*, 2013a), genetic mapping for quantitative traits of interest, and making basic and applied research on apomixis a reality.

Optimized nutritional quality assessments will be used to support the development of the ‘full-purpose crop’ approach—going beyond the primary traits of grain, pod and tuber yields to better match and balance human and animal nutritional needs (Blümmel *et al.*, 2013). In particular, the full purpose crop concept developed with the crop CRPs will allow across-crop adaptations that move beyond mono-dimensional improvements for primary produce yield. This will involve whole plant optimization, thereby improving the quantity and quality of crop residues at source. The rapidly increasing demand for monogastric meat in many countries requires new solutions to feed supply that do not compete for human food. Biological advances in entomology, modification and *de novo* synthesis of organisms and de-construction of ligno-cellulosic biomass (Blümmel *et al.*, 2014) provide the cutting-edge science needed to underpin the development of such feeds.

The flagship will use advances in phenotyping—including remote sensing with unmanned aerial vehicles, hyperspectral cameras, digital vegetative charting techniques and portable NIRS units—for *in situ* prediction of forage nutritional quality, as a basis for accelerating genetic gain in tropical forage systems. Building on work conducted by CIAT, the BecA-ILRI hub and other partners (Subbarao *et al.*, 2013; Subbarao *et al.*, 2015; Subbarao *et al.*, 2017), it will develop approaches to BNI in forages—work that adopts an innovative approach to both environmental and economic sustainability. New uses for endophytes, a novelty in tropical forages, and other microbial associations to enhance forage biomass and increase adaptation to biotic and abiotic stress factors will also be explored (Mutai *et al.*, 2017; Djikeng *et al.*, 2014; Ghimire and Craven, 2013; Ghimire *et al.*, 2009; Odokonyero *et al.*, 2016).

Under Cluster 3 (Feed Utilization) there will be a focus on on-farm opportunities that deal with feed processing options (Anandan *et al.*, 2012) to increase feed intake and reduce feed wastage, smart supplementation and ration balancing (Blümmel *et al.*, 2017), feed substitution and least-cost designs, and feed preservation and conservation. Off-farm work will focus on feed surplus to deficit transactions and on new technologies to upgrade lingo-cellulosic biomass for animal feed.

Under Cluster 4 (Scaling), systems approaches will be used to ensure that research advances are relevant and reach users at scale. This will include the co-development of informal and formal seed supply systems for specific feeds and forages (Hanson and Peters, 2003) taking into account the different needs and roles of women and men (Galiè, 2014; Kiptot and Franzel, 2011), and building on the participatory approaches to uptake of improved feeds and forages developed in SE Asia and Central America (Horne and Stür, 1999; Stür and Horne, 2001; Peters *et al.*, 2003).

The Cluster will develop and pilot business models for small-scale entrepreneurs at various levels along the feed value chain. This builds on recent success in this area e.g. our work with private feed manufacturers in India. The challenge is to find the appropriate degree of decentralization of feed manufacturing; the centralized model seems to have faltered for ruminant feed processing that is based on high bulk - low energy basal feed ingredients. Informal and formal seed supply systems will be further co-developed with private- and public-sector partners and through farmer-to-farmer networks, based on previous experiences made in the Livestock and Fish CRP (Livestock & Fish CRP, 2016). We have already piloted this approach in Ethiopia and have demonstrated that, with clear roles for the public and private sectors, demand can be stimulated. SMEs are then willing to invest as long as technical and business development support is available (Negassa *et al.*, 2016).

Feed production and supply chain analysis will be applied (Lundy *et al.*, 2014), together with feed certification models where appropriate. With development partners, notably GIZ, the flagship will test, validate and apply approaches to advance from proof-of-concept and piloting to scaling of feed and forage technologies, aiming to close yield gaps in animal productivity and reach millions of livestock producers. Through engagement with public and private sector actors, science will inform those actors and contribute to creating a conducive environment for sustainable intensification of livestock production systems through better feeding.

The flagship leadership will establish approaches for maintaining science quality across the flagship.

These will include internal peer review, mentoring schemes for junior scientists, pro-active targeting of special issues and conference symposia and internal Science Days to allow peer-to-peer feedback

and review of ongoing work. Classic approaches, such as peer-reviewed papers and participation in global science and development fora will allow debate and adjustments of the agenda.

2.3.1.5 Lessons learned and unintended consequences

We have learned many lessons from previous experience and these have been used to shape the current proposal. In summary, we acknowledge that much previous work has focused too much on only the supply of research outputs without taking sufficient account of the varying demands for research products and innovations related to livestock feeds and the institutional environment surrounding feed production and use. As a result, uptake of feed solutions has been lower than expected. This is also related to the often weak institutional environment in our target countries (e.g. seed multiplication, credit availability, quality of extension services, policies), or limited connectivity among NARS, development actors and extension. It is also clear that engagement with the private sector is key to taking our research to scale. For example, in the case of tropical forages, strong linkages with the private sector have not only helped to clarify demand but also to enhance dissemination. Although still in its early stages, tropical forage lines developed by CIAT have already been planted on at least 700,000 ha in over 35 countries. NARS have similar experiences leading to coverage of improved forages, for example across 120 million ha in Brazil. However, impacts of NARS are largely restricted to the national context and this is where the CG partners can step in.

Unintended consequences that might occur as a result of the work conducted in this flagship revolve around two areas: gender/youth and environment. With regard to gender/youth, feed and forage interventions might alter relationships in beneficiaries' households, including the empowering or disempowering of men and women or young people, and/or changes in responsibilities or workloads. This might create conflicts and result in negative consequences for individual family members, including women and young people. The flagship will include gender- and youth-disaggregated *ex-ante* and *ex-post* analyses to foresee, and avoid, such unintended consequences while extending the knowledge base on what works. With regard to environment, the development of highly productive feed/forage technologies could also result in further expansion of the area used for animal production. This may lead to e.g. deforestation, the loss of biodiversity and increased greenhouse gas emissions. To prevent this, strong links will be needed with policymakers, private sector actors, NGOs, donors and investors who support the sustainable intensification agenda. In this context, strong linkages will be established with flagships 4 and 5.

2.3.1.6 Clusters of activity

The core research agenda comprises four priority areas supported by W1/2 investment:

- Platforms, tools and analyses to prioritize, document and target context-specific feed and forage interventions (Cluster 1). W1/2 funds will support development of prioritization tools and foresight analyses and novel tools to enhance pheno-/genotyping efficiency.
- Development of new feed and forage options
 - Forage improvement to facilitate sustainable intensification, with an emphasis on the rapid inclusive growth trajectory and on integrating private-sector engagement (Cluster 2). W1/2 funds will support breeding of *Urochloa* and *Megathyrsus* and pheno-/genotyping of *Lathyrus* and *Pennisetum*.
 - Full-purpose crop improvement, making use of the synergies in crop–livestock interactions to maximize system efficiency (Cluster 2). W1/2 funds will support food-feed crops breeding of maize, sorghum and cowpea.
- Utilizing existing feed resources better (Cluster 3). W1/2 funds will support the development of small-scale feed processing and conservation options.
- Delivery and scaling, to ensure that the pathway from discovery to adoption and impact is completed, also considering gender/youth aspects and capacity development (Cluster 4 with flagship 5). W1/2 funds will support development of gender-/youth-sensitive feed business models and effective extension approaches for scaling forage/feed technologies.

The forage and feed development and utilization work (Clusters 2 and 3) will relate to Clusters 1 and 4 in an iterative and dynamic process of priority setting, targeting and scaling up, ensuring strong orientation to users' demands and maximizing impact at scale.

Cluster 1: Diagnosis of feed constraints and opportunities and development of smart approaches for prioritizing and targeting feed and forage interventions

Existing supply and quality of livestock feed and forages in target livestock systems varies markedly both spatially and across seasons. Demand for feed and forages to fulfil production needs for market oriented livestock production is also highly variable both spatially and temporally. The CRP's understanding of contextual constraints to better livestock feeding has been built through collaboration across CGIAR centres, NARS and IAR centres, partly through development of participatory, interactive tools such as FEAST and SoFT. This experience has helped to clarify the major system properties that influence the adoptability of different feed options.

In South Asia, the opportunities to introduce forages is limited because of small farm size, very high human population density and the need to grow food crops, hence the predominant focus on full purpose crops. In South-East Asia, to cope with small farm sizes, there is an opportunity for intensive forage production to be used strategically, complementing other feed resources. The same is true in parts of Africa but not in others where the opportunity for forages is greater, in some cases for on-farm use, but in others as a business. In LAC, pastures are the dominant land use. Well managed stress tolerant and productive forages have profound implications not only economically but also in terms of environmental services such as mitigating GHG and land degradation and liberating land resources.

In Cluster 1 we will build on our evolving understanding of how different feed options map onto local contexts. We will do this through building our work on prioritization tools but taking this further through foresight activities through which we map the adoptability of a range of feed options based on global spatial data layers that represent system properties such as land, labour and water availability, market access and population density, integrated with the foresight effort under flagship 5. The cluster will also further develop protocols for quantifying feed supply and demand at the level of regions within country with a view to supporting decision making. It will capitalize on new phenotyping capability at both farm (near infra-red spectroscopy) and landscape level (infrared reflectance and x-ray fluorescence spectroscopy) to inform decision making about enhanced feeding strategies at a range of scales including rangeland systems.

The cluster will refine approaches to decision making about best-bet feed interventions, capitalizing on expertise in CGIAR centres, building this into decision tools and thus making it available to livestock sector stakeholders at scale. *Ex-ante* and *ex-post* impact studies will be used to assess the economic, environmental and social impacts of the feeding strategies developed in this flagship.

Main research outputs

- Refined tools to analyse local, national and regional feed supply and demand, e.g. food-feed supply scenarios, NIRS. Application: global.
- Refined approaches to participatory identification of smart feeding strategies applicable at scale, e.g. development of decision-making tools in at least 2 priority countries (e.g. Ethiopia, India).
- Research priority setting based on *ex-ante* and *ex-post* impact assessments of feed and forage innovations taking into account gender roles and implications, e.g. estimation of adoption of forage hybrids through seed sales in at least 2 priority countries (e.g. Nicaragua, Kenya).
- Biomass and quality estimation tools for assessing feed resources and for mapping and monitoring trends in rangeland condition and vegetation cover, e.g. multi-scale/multi-sensor, near-earth and near-real-time using remote sensing in at least 1 priority country (e.g. Tunisia).
- Specialized databases, repositories, journals and interactive decision-support tools/maps for capacity development and utilisation of appropriate feed/forage options, e.g. FEAST, SoFT. Application: global.

Outcomes to 2022

1. Local, national and international research and development partners, the private sector, decision-makers and livestock producers are able to diagnose feed constraints and opportunities and to effectively prioritize and target feed and forage interventions, resulting in: a 10% increase in utilization of improved feeds and forages, a 20% increase in animal production (meat, milk or eggs) using improved feed and forage technologies, a 10% increase in accuracy for biomass and quality estimation and at least 250,000 annual visitors to global databases, repositories, interactive tools and maps and the *Tropical Grasslands—Forrajes Tropicales* journal website.

Milestones

- Research and development partners, decision makers and input suppliers use improved approaches for local, regional and national feed supply and demand scenarios in 3 priority countries⁵ (2019) and in a further 2 priority countries (2022).
- Research partners and the private sector use refined CGIAR stationary and mobile NIRS hubs in East and West Africa, South Asia and Latin America: in 3 priority countries (2019) and in a further 2 priority countries (2022).
- Research and development partners and the private sector (e.g. milk processors) use on-farm feed assessment tools in one priority country (2019) and in a further 3 priority countries (2022).

Cluster 2: Development of new feed and forage options

As demand for livestock products grows and the natural resource base for animal production becomes more constrained, the importance and monetary value of crop residues and forages is increasing rapidly. In response to farmer demands for improved feeds and forages, new technological options will be developed (in collaboration with the crop centres) through defining criteria and the selection, evaluation and breeding of full-purpose crops with improved residue fodder traits (Blümmel, 2010; Porqueddu *et al.*, 2016) and forage species that are more resilient to biotic and abiotic stress, more resource efficient and more productive (Rao, 2014; Rao *et al.*, 2015). Work will build on previous efforts by all partners and give new emphasis to the contribution of improved technology options to adaptation to and mitigation of climate change, and to water and nutrient use efficiency.

There will be a re-focussing of forage breeding to tropical Africa and Asia (see also Pengelly and Maass, 2017, recent MOU ILRI/CIAT to coordinate forage research), recognizing the heterogeneity in farm size and structure, importance of cut and carry systems, enabling environment, weak capacity in NARS on forages and weaker though emerging private sector engagement. The approach will capitalize on south-south linkages, in particular in respect to private sector collaboration (e.g. multi-locational testing, commercial seed production). More emphasis will be put on use and exploitation of existing genetic variation, with focused breeding on specific traits where existing variation is not sufficient, e.g. abiotic (e.g. drought tolerance) and biotic stress (diseases and pests), resource use efficiency (water, nutrients) and constraints to dissemination (seed production). The flagship is also including a new emphasis on rangelands and integrating dryland species, in particular for North Africa.

Main research outputs

- Forage (e.g. *Urochloa*, *Megathyrsus*, *Pennisetum*) and rangeland genotypes (e.g. *Lathyrus*) with potential to withstand abiotic and biotic stresses, reduce soil degradation and curb GHG emissions for use in at least 4 priority countries (e.g. Nicaragua, Tunisia, Kenya, Vietnam).
- Key full-purpose crop cultivars (e.g. maize, cowpea) that have enhanced residue fodder traits (in collaboration with other CRPs) for use in at least 3 priority countries (Nigeria, India, Ethiopia).
- Open-access genomic tools, forage crop ontologies and phenotyping platforms that increase breeding efficiency globally, e.g. dense maps and reference genomes to enable genomic selection.
- Increased rate of genetic gain (resource use efficiency, resilience, quality, yield) in apomictic

⁵ As defined in the Livestock CRP Full Proposal, p.29

Urochloa and *Megathyrsus maximus* (syn. *Panicum maximum*) hybrids. Application: global.

Outcomes to 2022

1. National and international research and development partners and the private sector are using CRP developed forage and rangeland resources (exploiting the genetic diversity available to enhance stress-tolerance, biomass productivity and nutritive value) in 30 countries in Tropical Africa, Asia and Americas and reaching producers who plant over 2 million ha.
2. New forage and crop cultivars, superior to local (based on food, feed and fodder traits weighted according to target domains), being scaled out by development partners, government agencies and the private sector and applied by at least 100,000 farmers in each of at least 7 priority counties and other locations.

Milestones

- Superior *Urochloa* and *Megathyrsus* cultivars available and disseminated by development partners and private sector partners in LAC priority countries (1 million ha by 2019) and further two priority countries in East Africa and Southeast Asia (2 million ha by 2022).
- Genetically-enhanced tropical forages (traits: resource use efficiency, resilience, quality, yield, seed production) disseminated by development partners and the private sector globally (100,000 farmers by 2019 and 600,000 by 2022).
- Superior rangeland options available and disseminated in North Africa (10,000 ha by 2019).
- Superior feed and forage cultivars (e.g. *Urochloa*) with higher biomass quantity and quality made available, disseminated and promoted by development partners, government agencies and the private sector and applied by 100,000 farmers in one priority country (2019) and by 100,000 farmers in each of a further 6 priority countries (2022).

Cluster 3: Using existing feed resources better

Feed shortage and high feed costs can be significantly mitigated by making better use of the resources that are already available. This leads to reduced feed costs and more efficient production of animal-source food and hence to a reduced environmental footprint. For on-farm feed resources this includes preservation and storage (hay, silage) to balance seasons of plenty and deficit, context specific feed processing targeted to on-farm conditions (productivity level, feed demand, labour, investment ability), smart supplementation, matching of key nutrients to actual animal performance, least cost ration and feed substitution design, and biological, chemical and physical upgrading of feed, fodder and forage biomass. For off-farm feed resources, mapping of feed resources and demand at a range of scales to encourage and facilitate feed surplus-to-deficit transactions through feed markets, engaging a range of public and private value chain actors, is needed.

The tools described in cluster 1 will be used to identify the appropriate approaches in different contexts, taking a value chain approach. Many interventions aimed at better use of existing feed resources offer opportunities for private-sector engagement in decentralized feed processing, especially for SMEs. They also often result in income and employment opportunities, especially for young people and women.

For the fragile growth trajectory, improved utilization of rangeland feed resources will be a focus, together with rangeland conservation and rehabilitation measures (with Clusters 2 and 3 of flagship 4). New biological, physiological and chemical approaches, often designed and developed for second-generation biofuel technologies, are becoming available and will be explored for the economically effective release of sugars from the 10 - 50 billion tonnes of ligno-cellulosic biomass available annually globally from crops and rangelands, potentially making some of them available for livestock.

Main research outputs

- Viable strategies for matching feed processing options with small capacity, e.g. on-farm feed processing setups in at least 1 priority country (e.g. India).
- Scalable drying and ensiling protocols for small-scale producers, to conserve feeds, forages and by-products, e.g. on-farm, communal and private sector feed preservation approaches in at least 1 priority country (e.g. India).

- Agronomic practices that improve the productivity, nutritional quality and resilience of diverse grass, legume and rangeland technologies across environments in at least 3 priority countries (e.g. Tunisia, India, Ethiopia).
- Improved understanding of gender roles in feeds and forages in mixed crop-livestock systems and the identification of investable solutions for women in processing technology in at least 2 priority countries (e.g. Nicaragua, Ethiopia).
- Optimized feeding strategies, including rations and processing, to improve animal productivity, including rangelands and monogastric production, reducing feed costs and labour requirements in at least 1 priority country (e.g. Tunisia).

Outcomes to 2022

1. National and international development partners, government agencies and extension services, the private sector and community-based organisations in 3 priority countries are using CRP-related research outputs for better utilization of existing and novel feed and forage resources. This will be through (a) scalable processing technologies, (b) management strategies to conserve and rehabilitate rangelands and (c) diet formulation that increases productivity while reducing overall feed and forage costs and environment impacts.
2. Livestock producers in 3 priority countries apply management strategies to conserve and rehabilitate rangelands and pastures while ensuring ongoing ability to produce, preserve and store feed biomass and use diets that increase productivity and reducing feed and forage costs and environmental impacts (with flagships 4 & 5).

Milestones

- Well-targeted training modules in feed processing and feeding are used by national and international development partners in at least 1 priority country (2019).
- Scalable and gender-responsive processing technologies are used by national and international development partners, the private sector and community-level organizations in at least 1 priority country (2019).
- Livestock producers apply management strategies to conserve/rehabilitate rangelands and use diets that increase productivity in 1 priority country (2019) and in a further 2 (2022), respectively.

Cluster 4: Facilitating the delivery and uptake of feed and forage technologies

This Cluster will develop approaches to enhancing the uptake of improved feed options developed in this flagship and elsewhere. This will involve developing a better understanding of the organizational constraints to uptake of new feeding strategies, including the supply of germplasm. The Cluster will interleave with flagship 5 and will be the bridge between the development of new feeding strategies (in this Cluster) and their adoption at scale through institutional innovation (flagship 5).

Seed supply for planted forages is often an impediment to uptake. The Cluster will therefore test organizational innovations to overcome the germplasm constraint, including working with private sector actors, community seed production groups and the public-sector research system. The work will involve development of business plans for SMEs and farmer cooperatives, value chain interventions and collaboration with the development community, bringing in their business expertise (e.g. GIZ as strategic CRP partner). The work will build on e.g. the Feedseed project in Ethiopia which spawned a number of small-scale private seed producers and which highlighted the catalytic role that CGIAR can play in bringing the public and private sectors together. It will also take advantage of the growing interest in Africa as the next market for private seed suppliers, evidenced by some companies opening offices (Tropical Seeds⁶) and making investments (e.g. DLF in South Africa⁷).

A further barrier to improved feeding concerns arrangements for transport and processing of bulky feeds such as crop residues and agro-industrial by products. Organizational innovations will be

⁶ <http://www.tropseeds.com/research-production/tropical-seeds-in-asia-and-africa/>

⁷ <http://seedworld.com/dlf-seeds-zaad-holdings-joint-venture/>

explored including community ownership of processing facilities and collaboration with transporters and private processors to develop compacted feeds which are more amenable to economic transport. We will experiment with public-private partnership models to enhance supply of high quality feed to smallholder farmers, drawing on experiences in the crop sector, e.g. on the N2Africa project.

We will collaborate with development projects and NARS to leverage the scaling of proven technologies and approaches, including developing model agreements with NGOs to scale approaches and technologies to improve feed supply building on the experience of Africa RISING. We will continue to experiment with various scaling strategies such as innovation platforms at a range of scales, engaging in policy roundtables and media and the use of ITC and social media to enhance uptake.

Main research outputs

- Business models and road maps for gender- and youth-sensitive, small-scale seed supply, feed transaction and processing enterprises in at least 4 priority countries (e.g. Kenya, Tunisia, Tanzania, Ethiopia).
- Recommendations for developing links between private-sector actors and small-scale producers for the delivery of forage and feed technologies at scale in at least 4 priority countries (e.g. Kenya, Tunisia, Tanzania, Ethiopia).
- Recommendations for effective extension and outreach approaches for scaling forage and feed technologies and approaches (evaluated for their cost-effectiveness, sustainability, benefits to women and young people and accountability to clients) in at least 3 priority countries (e.g. Kenya, Tanzania, Tunisia).

Outcomes to 2022

1. Increased delivery and uptake of feed and forage resources and enhanced participation of women through proof-of-concept scaling, business model development and value-chain approaches by development partners, the private sector (feed and forage traders, feed processors), NARS, and small-/medium-scale farmers (1 million by 2022) across diverse environments in priority countries and other locations in LAC, North and East Africa and South and Southeast Asia.

Milestones

- National and international development partners and other value-chain actors pilot test at least 4 extension approaches (including at least 1 that improves women's access to information) in at least 1 CRP focus country (2019).
- National and international development partners and other value-chain actors adopt and scale up at least 2 of the tested extension approaches (including at least 1 that improves women's access to information) in 5 priority countries (2022).
- Increased uptake and impact of improved feeds and forages and processing technologies, with a particular focus on women and young people in 3 priority countries (2019) and in a further 2 priority countries (2022).
- Inclusive business models for improved supply of forages and feed processing systems tested and validated by multiple partners across 4 priority countries (2019) and in a further 3 priority countries (2022).
- Co-creation with development and private-sector partners of up to 100 SMEs in decentralized feed processing, forage marketing or seed multiplication, in 4 priority countries (2022).

2.3.1.7 Partnerships

This flagship's partnership strategy is driven by its ToC and the skills, expertise, facilities and capacity needed along discovery-to-delivery pathways. The combined comparative advantage of the flagship's core program partners guide the choice of further partners needed to bring in additional capacity. Partnerships are also influenced by the target geographies of the CRP. Comparative advantage in feeds and forage technologies is provided by ILRI, CIAT and ICARDA, each with relevant expertise, resources, and genebanks. The choice of partners is largely determined by a) technical, managerial and operational capacities of the partner, b) where the partner is located, c) the stage in the discovery-to-

scaling up process and d) existing track record of collaboration. Key cross-CRP partnerships, especially on ASF, will be deepened through the Full-Purpose Crops Initiative and BNI Consortium.

The core flagship partners: CIAT, ICARDA, ILRI and SLU, have a strong record on forage development and integration into small- and medium-scale systems, generating economic and environmental benefits. CIAT, ILRI and ICARDA have extensive forage collections to select materials for a wide range of agro-ecologies and livestock production systems. This is complemented by forage breeding at CIAT, for which there are few alternative providers. ILRI has strong links with crop centres to develop full-purpose crops, which represent a unique global opportunity. ICARDA has strong expertise and networks in dryland systems. CIAT and ILRI are linked with the BNI Consortium coordinated by JIRCAS and the Climate-smart *Urochloa* project coordinated by BecA-ILRI. CIAT, ILRI, ICARDA and SLU are researching links between feeds and forages, livestock and the environment. GIZ brings a strong demand orientation and a focus on value chains, business models and scaling up (GIZ, 2015). The BecA-ILRI Hub, ILRI, CIAT and ICARDA have state-of-the-art bioscience facilities that include long-term strategic research capacity on feeds and forages.

Advanced research partners: To develop diagnostic and decision-support tools the flagship will collaborate with upstream research and development partners. These will include FAO, CSIRO and CIRAD, all of whom have databases on tropical feed resources. CSIRO has a strong track record of developing decision-support tools in agriculture. The development of new feed and forage options requires access to state-of-the-art knowledge and facilities in genotyping, phenotyping and bioinformatics, so it is important to be linked with cutting-edge research groups such as the UK's Earlham Institute and Institute of Biological, Environmental and Rural Sciences. Access to genetic material beyond the CGIAR will be provided through partnerships, for example EMBRAPA. Work on the de-construction of ligno-cellulosic biomass will involve collaboration with organizations such as Michigan State University. Continued collaboration with regional institutions such as CATIE will allow up- and downstream advances in understanding and managing the livestock–environment interface.

Partners for leverage and scale: Catalysing innovation and reaching impact at scale in the feeds and forage sector will be facilitated through links with service providers, organizations such as national dairy boards (e.g. in India) and private-sector feed and seed suppliers. In the case of the latter, we already have fruitful collaborations with Dodla Dairy and Fertile Green Inc on dairy feed value chain development in India and with Dow Agrosiences and Grupo Papalotla for forage hybrid seed dissemination. Collaboration with GIZ as a strategic partner will support innovation from proof of concept to scale in priority countries. The final piece in the uptake of new feed and forage technologies is strong partnerships with national research programs and universities in priority countries and with development organizations such as SNV, Solidaridad Network and Heifer International. These partnerships will test, validate and support technical and organizational innovations and the links will be forged mainly through flagship 5.

2.3.1.8 Climate change

Enhanced feed and forage production is critical for both climate change adaption and mitigation. Recognizing that feed and forage production is the largest agricultural land use worldwide (Peters *et al.*, 2013), there is considerable potential for widespread impact on climate change goals through these land-based interventions.

The flagship will develop technologies that contribute to adaptation, for example by enhancing stress tolerance among improved forage lines. Work on the use of remote sensing to assess range vegetation quality will also support feeding strategies that take account of changing climatic conditions.

Mitigation will be addressed through a range of research strands including work on BNI and enhanced carbon sequestration. In addition, increasing livestock productivity through higher feed quality in forage-based systems will reduce methane emissions per unit of livestock product, through better partitioning of energy to production as opposed to maintenance of animals (Hatew *et al.*, 2015). Improved resource-use efficiency will also help mitigate the effects of climate change through reduced use of external inputs, especially those based on fossil fuels (Peters *et al.*, 2013).

Close links with the policy community will be needed to avoid the expansion of feed and forage production into non-agricultural areas, such as forests, and other natural eco-systems with high conservation value and that play an important role in mitigation. The system level beneficial impacts of this flagship on climate change will be realized through collaboration with the flagship 4.

2.3.1.9 Gender

Gender is an integral part of the problem analysis and priority setting process across the program (see Annex 3.3). This flagship will translate the gender strategy into concrete activities, including developing gender capacities, developing approaches that enable women to improve their participation in value chains and increasing their access to and control of resources, technologies, and the benefits of their work. For example, feed chopping and collection are often carried out by women and entail considerable drudgery. This can be alleviated through simple mechanization and more on-farm biomass productivity. Women typically, but not exclusively, maintain smaller livestock, such as poultry, pigs and small ruminants, which have different feed demands and costs than larger livestock and thus different feed needs. This will be incorporated in the flagship's agenda-setting.

Gender-based feed and forage crop variety preferences will be assessed and gender analysis will consider the demand for and uptake of forage solutions, and develop an understanding of gendered forage and feed technology dissemination and uptake pathways. Differences in labour demand and preferences of women on forage and feed production or in sourcing and processing feeds will be researched. Differential access to land will also be considered. Other aspects include intra-household distributional impacts of feed and forage innovations. This analysis will inform technology development and delivery systems so that both women and men benefit. Policy aspects affecting women's ability to access and use feed resources will be addressed with flagship 5.

Youth: Opportunities exist to engage young people in the development of new small-scale businesses in feeds and forages. Possibilities include the involvement of young people in technologies that connect farmers to feed and forage supplies, in producing feeds and forages (for example in irrigation schemes) and in feed formulation. Further, young people can be supported to produce and market high quality forage seeds, thereby ensuring better year-round feed availability—a major constraint at present. Activities will identify entry points for young people, identify constraints to participation, and developing a youth engagement strategy (see Annex 3.4).

2.3.1.10 Capacity development

Capacity development will build on approaches developed during the Livestock and Fish CRP (see Annex 3.2). We will focus on two elements of the CGIAR capacity development framework:

- Design and delivery of innovative learning materials and approaches through using methods such as new ICT-based approaches.
- Development of future research leaders through fellowships and institutional strengthening.

Learning approaches, including blended learning for farmers and development practitioners, which is being developed for use in conjunction with decision-support tools (e.g. FEAST, SoFT), will be extended, while their efficiency and reach will be improved using novel ICT approaches. Training of trainers will be addressed through incorporating approaches such as new instructional design. Big data approaches will be brought into play to support a broad audience ranging from development, research and education institutions, to policymakers, the private sector and farmers/farmer associations. Integrated platforms (e.g. NIRS) will further facilitate scaling up. The flagship will continuously train and receive inputs from PhD, MSc and undergraduate students.

In 2017, the CapDev team of the CRP, is doing capacity needs assessment (CNA) for all flagships. This will identify capacity development needs at individual, organizational and systems levels in the priority livestock value chains. The assessment will seek to evaluate partners' roles in the capacity development processes of projects. The evaluation will serve to focus the roles and responsibilities of partners and other stakeholders in terms of planning actions to support the strategy's results.

2.3.1.11 Intellectual assets and open access management

Robust intellectual asset (IA) management, open access and research data management and communications will be followed as these are proven to help in achieving uptake and outcomes (sections 1.0.12, 1.0.13 and 1.0.14 and annexes 3.8, 3.19, and 3.10.7). Specific issues relevant to this flagship are listed here.

The flagship works with private-sector organizations to develop and commercialize its technologies. This requires negotiation and active legal engagement to safeguard open access while protecting the interests of all partners in line with CGIAR principles. Agreements with companies to disseminate products resulting from forage breeding efforts are normally time- and location-limited. Such commercial cultivar intellectual property (IP) management for bred forages mainly applies in LAC and differentiated approaches are followed elsewhere. For full-purpose crops, the flagship works closely with other CRPs using crop-specific delivery pathways. For its forage genetic resources, the flagship complies fully with the Convention on Biological Diversity (1993), International Treaty on Plant Genetic Resources for Food and Agriculture (2004) and Nagoya protocol (2014).

Most information products developed by the Livestock and Fish CRP are already open access. This includes materials accessible through [CGSpace](#) and the open access *Tropical Forages–Forrajes Tropicales* journal. A weaker element is access to a wide range of limited access journal articles. The flagship will reserve funds to supplement bilateral projects to pay for open access fees for selected articles. The longer-term strategy is to fully budget these open-access costs in bilateral projects.

The flagship produces various online products and tools whose content is open access. Partners manage feed databases with various degrees of openness. The flagship will work to ensure that these are as open as possible. Adequate documentation and accessibility of data will be ensured through open access and data management plans and by allocating funds for proper curation and publishing.

2.3.1.12 Flagship management

Implementation will be led by a Flagship Leader (FL), supported by a leader for each cluster (CL) and an administrative support. The primary roles of this core team are to develop and update the vision for the flagship's research agenda and impact pathways, monitor the quality and delivery of knowledge and technology outputs, and report as required. Responsibility for implementation and delivery of research lies with CGIAR-centres, core partners and additional collaborators.

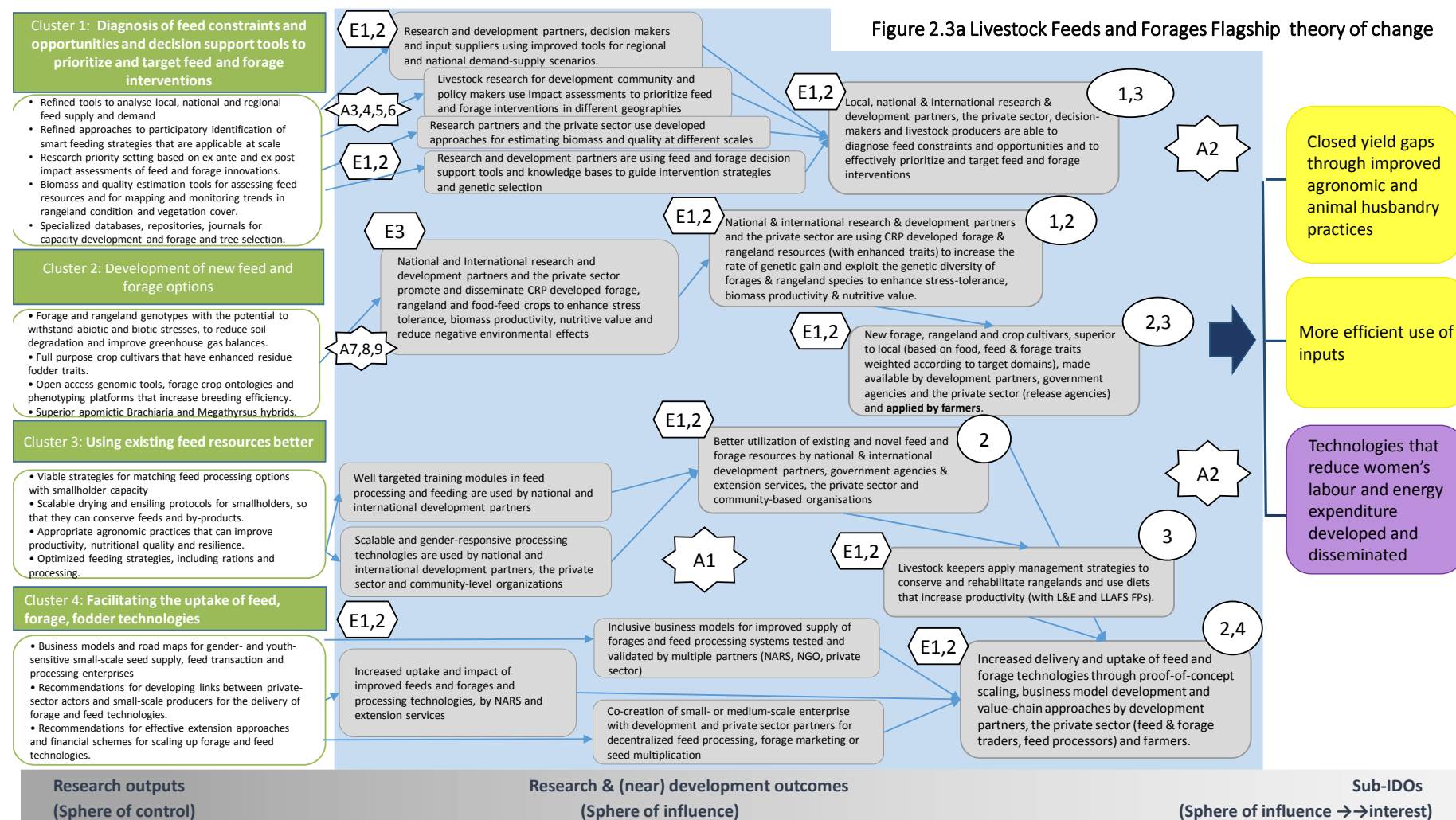
The FL will guide priority strategic research and allocation of W1/2 resources as well as any strategic exploration of new research areas; guide development of bilateral projects to ensure alignment to the flagship and their ability to contribute to strategic synthesis funded by W1/2; coordinate reporting; lead cross-flagship initiatives; support and sometimes lead resource mobilisation and lead bi-monthly meetings (face-to-face or virtual).

CL will have a scientific leadership role, they will also contribute to reporting, together with PIs of aligned projects and Centre focal points. CLs support the FL in developing the flagship strategy, and will guide research in their clusters and monitor science quality of outputs. They will lead science quality of all strategic research supported by W1/2 resources. Each CL will identify a small group of key scientists across the CRP to develop innovative research design and to review new initiatives.

The flagship will be led by Michael Peters (CIAT); 20% of his time will be supported by W1/2, with 20% administrative support, and an annual flagship meeting. Cluster leaders will be: C1 A. Duncan (ILRI), C2 V. Castiblanco (CIAT), C3 M. Blümmel (ILRI), and C4 U. Ohmstedt (CRP-CIM staff housed in CIAT). Cluster leaders contribution will not be specifically resourced beyond their agreed participation in cluster outputs. A CIM-supported position in C4 (U. Ohmstedt) will connect to GIZ (and its cross-CRP scaling task force) and to flagship 5.

2.3.3 Annex

Figure 2.3a Livestock Feeds and Forages Flagship theory of change



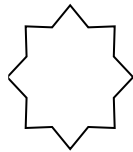


Figure 2.3b Livestock Feeds and Forages Flagship Theory of Change: Assumptions, Change Domains and Enabling Cross-cutting Actions

Assumptions	
A1	Research outputs on better use of feed gain attention of large-scale development actors
A2	Better matching of feed options to local constraints is the limiting constraint to enhanced feeding
A3	Active networks in place to allow dialogue between researchers and next users
A4	Next users see the importance of better intervention strategies beyond simply feed genetic selection
A5	Impact assessments are considered independent and credible by next users
A6	Tools and approaches are considered appropriate, usable and fit for purpose by next users
A7	Continued support by the public and private sector
A8	Feed is a constraint to animal productivity
A9	Feed sourcing has a high labour demand, in particular for women and youth

Enabling cross-cutting actions	
E1	"Next user" capacity development
E2	Consideration of gender & youth issues in technology, business models & delivery system development and dissemination
E3	Evolving markets

Domains of Change	
1	Changes in local, national and international research and development systems
2	Changes in markets, enterprises and consumer behaviour
3	Changes in producer systems (producers and communities)
4	Changes in policy and investment systems for scaling

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